



Geographic distribution of the Pygmy Squirrel *Sciurillus pusillus* (É. Geoffroy-St.-Hilaire, 1803) (Rodentia: Sciuridae) in the northwestern Amazonia, southern Colombia

María C. Calderón-Capote^{1, 2*}, **Juan F. Díaz-Nieto**^{3, 4} and **Hugo Fernando López-Arévalo**^{1, 2}

1 Grupo de Mastozoología Universidad Nacional de Colombia, Facultad de Ciencias, Universidad Nacional de Colombia, Entrada Calle 53, Edificio 425, Bogotá D.C., Colombia

2 Grupo en Conservación y Manejo de Vida Silvestre, Instituto de Ciencias Naturales, Facultad de Ciencias, Universidad Nacional de Colombia, Entrada Calle 53, Edificio 425, Bogotá D.C., Colombia

3 Department of Ecology, Evolution, and Behavior; and J.F. Bell Museum of Natural History, University of Minnesota, 1987 Upper Buford Circle, Saint Paul, MN 55198, USA

4 Área de Ciencias Biológicas, Escuela de Ciencias, Universidad EAFIT.

* Corresponding author. E-mail: mccalderonc@unal.edu.co

Abstract: We evaluated the occurrence of *Sciurillus pusillus* in Colombia and present the first confirmed records of the species in the country based on material deposited at Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Villa de Leyva (IAvH, former INDERENA). The mentioned material was collected in two localities from vicinities of town La Chorrera, Igara-Paraná River, Amazonas Department of Colombia. Additionally, we provide a description of the baculum from one of the specimens herein recorded from Colombia.

Key words: Amazon, ardillas, baculum, Pigmy Squirrel

The South American Pigmy Squirrel *Sciurillus pusillus* (É. Geoffroy St.-Hilaire 1803) is the smallest tree squirrel in the Western Hemisphere and constitutes a monotypic lineage that represents an apparent early diversification event in the history of the family Sciuridae (Mercer and Roth 2003). É. Geoffroy St.-Hilaire (1803) was the first who formally described the species and allocated it under the genus *Sciurus*. Later, Allen (1914) transferred the species to the genus *Microsciurus* and in the same year, Thomas (1914a) recognized the distinctiveness of this squirrel from other forms of the genus *Microsciurus* and described the new genus *Sciurillus* with its only species, *S. pusillus*. A detailed review on the taxonomic and nomenclatural history of the species can be found elsewhere (de Vivo and Carmignotto 2015). Although four subspecies have been described for the species, for the present work, we follow the rationale and arrangement provided by de Vivo and Carmignotto

(2015) who consider *S. pusillus* to be a monotypic species, with the names *glaucus*, *hoehnei* and *kuhlii* as junior synonyms. Herein, we provide the first voucher specimens that confirm the presence of this rare pygmy squirrel in Colombia; additionally, we describe the baculum of one male specimen and compare it with the only available description of the penis bone for this species (Anthony and Tate 1935).

To date, *Sciurillus pusillus* is known from few localities showing an apparent disjunct distribution between eastern and western lowland rainforest of South America. Eastern populations are found in northeastern Brazil (north and south of the Amazon River), French Guiana, Guyana, and Suriname (Wilson and Reeder 2005; Thorington et al. 2012; Jessen et al. 2013; de Vivo and Carmignotto 2015), whereas western populations are only recorded for the Amazon of Peru, south of Putumayo River (de Vivo and Carmignotto 2015). As mentioned in detail by de Vivo and Carmignotto (2015) the species has not been recorded in Ecuador or Venezuela; for Colombia although all of the faunal compilations of this country have included the species, none of them offered evidence supporting such claim (Cuervo Díaz et al. 1986; Rodríguez-Mahecha et al. 1995; Alberico et al. 2000; Solari et al. 2013). In particular, Alberico et al. (2000) and Solari et al. (2013) reported the presence of *S. pusillus* for the Caquetá Department based on material apparently deposited at Instituto de Ciencias Naturales, Bogotá (ICN) and Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Villa de Leyva (IAvH, former INDERENA) but no reference to specific locality or catalog numbers was provided.

In order to confirm the presence of *Sciurillus pusillus* in Colombia we visited the mammalogy collections at IAvH and ICN where Alberico et al. (2000) suggested that material from this species was deposited. For identification purposes we followed the descriptions of Anthony and Tate (1935), Moore (1959), Husson (1978) and de Vivo and Carmignotto (2015). External measurements were transcribed from specimen tags, and given the severe fragmentation of the available skull (see below) we could only record the upper molar row (UMR) and lower tooth row (LTR) following Husson (1978). Additionally, the baculum of one male specimen examined was extracted and treated with a clearing and double staining technique of cartilage and bone following Wassersug (1976).

After examining the mentioned collections, we did not find any specimen of *Sciurillus pusillus* at the ICN, however we found two specimens of the species, one male (IAvH 690) and one female (IAvH 2631), at the Instituto Alexander von Humboldt, Villa de Leyva. The male IAvH 690 is a fluid specimen with the skull extracted and partially broken. This specimen was collected at the right bank of the Igara-Paraná River, 10–15 km downstream from town La Chorrera, Department of Amazonas, Colombia (approximate coordinates: 01°28'56.2" S, 072°43'26.7" W) (Figure 1). The second specimen found (IAvH 2631) corresponds—according to the IAvH catalog—to a skin with fluid preserved body; nonetheless, the carcass and skull are lost. This specimen was collected at the headwaters of Igara-Paraná River, 50 km northwest from town La Chorrera, Department of Amazonas (approximate coordinates: 01°00'47.7" S, 073°00'09.1" W) (Figure 1).

The two Colombian specimens follow largely the diagnostic characters described for the species (see Buffon 1789; Anthony and Tate 1935; Moore 1959; Husson 1978, de Vivo and Carmignotto 2015) and the external measurements of both specimens coincide with the range of variation reported from other localities (Table 1). Externally, the examined material has gray

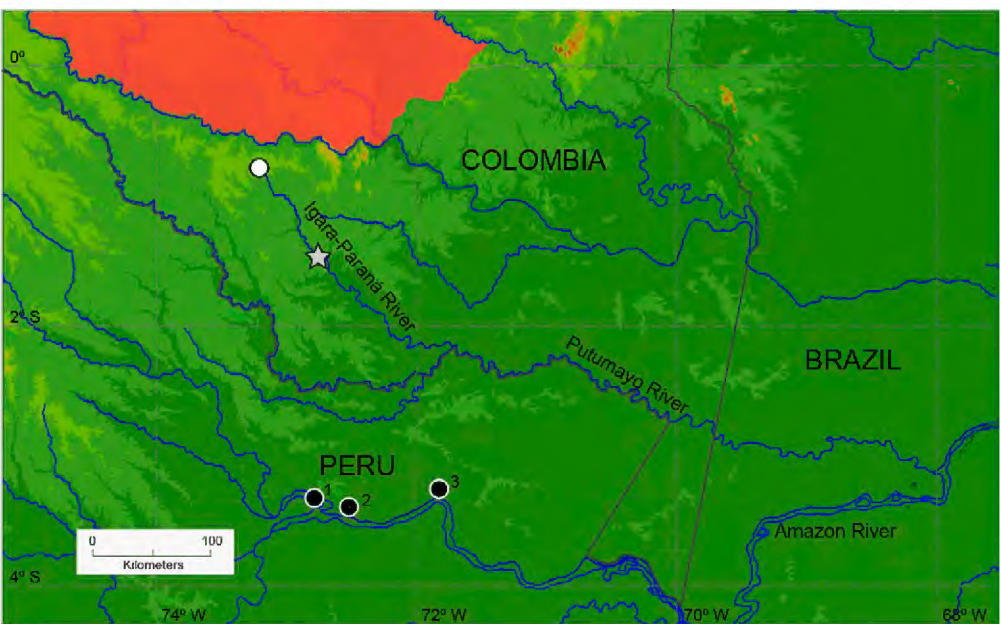


Figure 1. Records of *Sciurillus pusillus* in Colombia and northern Peru. The open circle (IAvH 2631) and star (IAvH 690) correspond to localities from the Amazonas Department, Colombia. Filled circles represent Peruvian localities from Santa Cecilia (1), Quebrada Oran (2) and Pebas (3); for coordinates and complete locality data see de Vivo and Carmignotto (2015). Red polygon shows the Caquetá Department (Colombia), locality that was broadly defined by Alberico et al. (2000) and Solari et al. (2013) for the distribution of the species in Colombia and from which we did not find any specimens.

olive dorsal coloration washed with yellow, reddish venter, hairs of the tip of ears as the head and white postauricular patches (Figure 2). Cranially, Moore (1959) proposed the combination of 12 characters as diagnostic for the monotypic genus *Sciurillus*. Because of the fragmentation of the only skull available (IAvH 690) we could only observe six of Moore’s cranial characters (characters 1, 2, 7, 8, 10 and 12): a single transbullar septum, the absence of postglenoid foramen, the foramen at the base of the pterygoids, the lack of frontoparietal suture, a rounded appearance of the orbit and the lack of superior process of the zygomatic arch. Although our material follows largely Moore’s description, two characters show variation; in particular, the frontoparietal suture is visible (opposed to character 10) and the superior process on the jugal is weakly developed (opposed to lack of such process, character 12). The mandible shows short angular and coronoid processes

Table 1. External measurements and two dental measurements of *Sciurillus pusillus* from different localities: Cayenne, French Guiana (for measurements see Buffon [1789: 263] and for holotype see de Vivo and Carmignotto [2015: 7–8]); Saut Tamanoir, French Guiana and Tapajós, Brazil (Anthony and Tate 1935: 12–13); Suriname (Husson 1978: 381–382) and Igará-Paraná River, Amazonas, Colombia based on IAvH 690 (male) and IAvH 2631 (female). For the French Guiana and Tapajós we present an average (number of individual in brackets). LT of IAvH 690 was re-measured without the pencil hairs. HB: head and body length, LT: tail length, HF: hindfoot length, UMR: upper molar row, LTR: lower tooth row.

Measurements	Cayenne, French Guiana MHNH 312 Holotype	Saut Tamanoir, French Guiana FMNH 21790, 21788, 21789	Suriname No. 17221	Tapajós, Brazil AMNH 94746, 94752, 95729, 95730, 95734	Amazonas, Colombia IAvH 690, 2631
Sex	♂	♂ (2)	♀	♂ (5)	♀ (4)
Weight (g)	–	–	–	–	–
HB	109.2	104.5	97	92.4	100
LT	83.8	98	114	104.6	81
HF	–	24	25	25.6	27.7
Ear	–	–	–	–	–
UMR	–	3.75	4.0	3.85	3.75
LTR	–	–	4.3	–	–



Figure 2. Fluid preserved specimen of *Sciurillus pusillus* (IAvH 690) in dorsal (top), ventral (middle), and lateral (bottom) views. Postauricular patch (P. Pat). Scale 10 mm.

(Figure 3). Based on the morphological characters of the two skins and the craniodental characters that we could record, we conclude that the specimens IAvH 690 and 2631 follow the description of the species *S. pusillus* as currently recognized. Furthermore, the specimens examined provide evidence of the material that Alberico et al. (2000) probably were referring to for including the species *S. pusillus* in the list of mammals of Colombia.

The baculum or penis bone has been important in the systematics of squirrels and in some instances has even proven to be a useful character for species identification (Thomas 1915; Wade and Gilbert 1940; Didier 1955; Anderson 1960; Burt 1960; Hooper and Musser 1964; Patterson and Thaler 1982; Pessôa et al. 1998; Bezerra 2005; Rocha-Barbosa 2012). The baculum of specimen IAvH 690 has a distinctive axe-like shape in lateral view, where the shaft resembles the handle and the distal portion of the baculum follows the shape of the axe head (Figure 4). The base of the baculum is thick and cylindrical and tapers distally along the shaft forming a neck or constriction. At this point the shaft expands into the apical blade (dorsal process) and the ventral process. The apical blade is broad and long and expands distally; the ventral process is shorter and has almost the same width along its length (Figure 4). The apical blade is concave on the right side and convex on the left side. In ventral view, the baculum shows a strong longitudinal curvature to the right (Figure 4). A rounded

cartilage is present on the right side of the shaft with a diameter about half of the length of the baculum; the edge of this cartilage contains a line of buds providing a crenulated appearance (Figure 4). Unlike the baculum of specimen IAvH 690, the baculum of *S. pusillus* illustrated by Anthony and Tate (1935: 3; Figure 4) does not present the characteristic “axe-like” shape or the well developed ventral process and no cartilaginous tissue was recovered and therefore not described in that report. Additionally, Anthony and Tate (1935) do not mention the presence of any longitudinal curvature of the baculum they examined, which is a character that we clearly observe in the Colombian specimen; nonetheless, we have to consider that the unknown preservation conditions of the examined material could have affected the morphology (i.e., longitudinal curvature) of the baculum.

The specimens here presented are the first to confirm the presence of *Sciurillus pusillus* in Colombia; nonetheless, as noted above these are not the first records for the species in the western Amazon, our material is approximately 220 km north from Peruvian localities in the Region of Loreto (de Vivo and Carmignotto 2015) (Figure 1). Although Putumayo River is the only conspicuous barrier between the Colombian and Peruvian records, many Amazonian rivers have shown not to be strong barriers for the dispersal of small mammals (Gascon et al. 2000; Patton et al. 2000).



Figure 3. Skull and mandible of *Sciurillus pusillus* (IAvH 690). Top to bottom: dorsal, ventral and lateral views of skull, and lateral view of lower jaw. Scale 10 mm.

More precisely, there are now several examples of small terrestrial and arboreal mammals with populations occurring on either side of Putumayo River (Gómez-Laverde et al. 2004; Voss et al. 2009; Rossi et al. 2010; Díaz-N 2012). Although our records add important information to the limited knowledge on this species, many gaps still remain in our understanding on the geographical and species limits within this clade. Moreover, several lines of evidence, including molecular divergence and morphological variation, might suggest that the monotypic genus *Sciurillus* has more diversity than what is currently recognized. For instance, Roth and

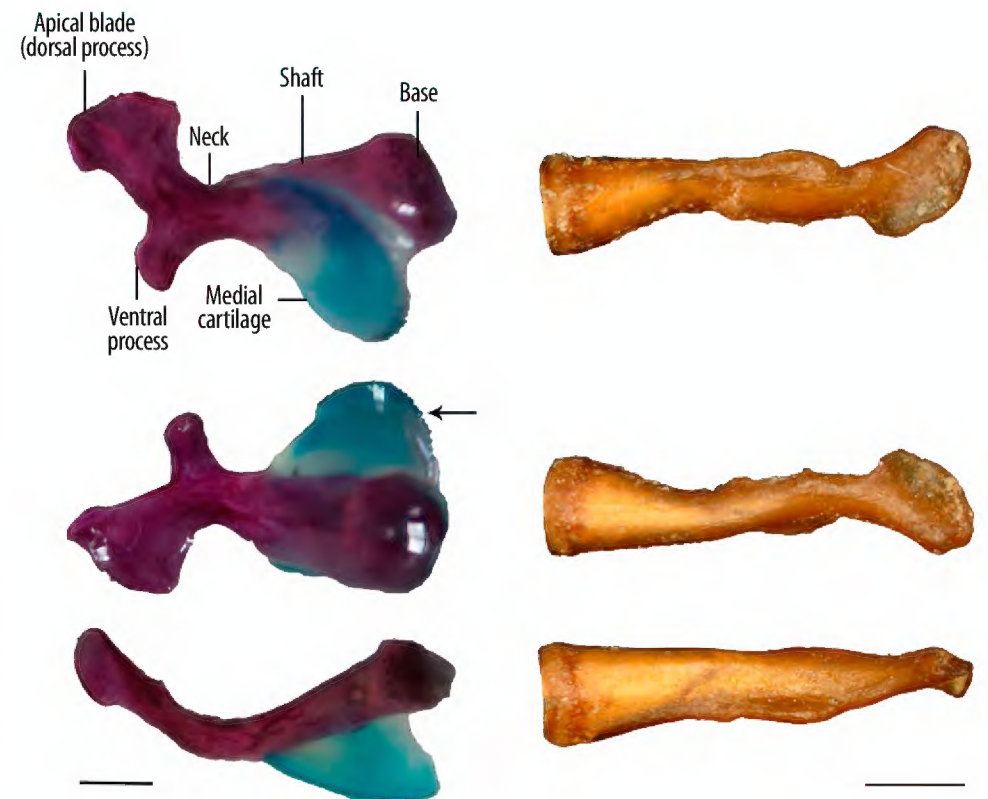


Figure 4. Baculum of *Sciurillus pusillus* (left: IAvH 690; right: AMNH 93154). Top: right lateral view; middle: left lateral view; bottom: ventral view; arrow: cartilage showing the series of buds along the edge. Scale 1 mm.

Mercer (2008) found that haplotypes of *S. pusillus* from French Guiana (USNM 578014) and Loreto department in Peru (LSUMZ 27994) shared their most recent common ancestor 10 Ma ago during the mid Miocene, a time in which other South American mammalian taxa experienced elevated diversification rates (Jansa et al. 2013). Additionally, the striking differences in baculum morphology between material from the western Amazon in Colombia (IAvH 690) with respect to Brazilian material from the eastern Amazon basin (AMNH 93154; Figure 4) could also provide evidence that *S. pusillus* might be a composite species. Clearly, the genus *Sciurillus* is in need of an urgent taxonomic revision in order to clarify its diversity and the geographic boundaries of the lineages that are part of this genus.

ACKNOWLEDGEMENTS

We thank Claudia A. Uribe Medina from IAvH and Dr. Robert S. Voss at the AMNH for allowing us access to material under her care. Staff of department of “Informática de la Biodiversidad” from ICN provided assistance with the photographs of figure 2 and Paúl M. Velazco helped us with images of AMNH material from Figure 4. We also thank Dr. Adriana Jerez from the Biology Department, Universidad Nacional de Colombia for her kind assistance during the laboratory work related with clearing and staining of the baculum. J.F.D. is currently supported by a Francisco José de Caldas Fellowship from the Colombian department of science, technology, and innovation (COLCIENCIAS). Finally, we thank Marcela Gómez-Laverde for her comments to an earlier version of this manuscript and James L. Patton for his useful suggestions and providing relevant literature that improved the quality of this manuscript.

LITERATURE CITED

- Alberico, M., A. Cadena, J. Hernández-Camacho and Y. Muñoz-Saba. 2000. Mamíferos (Synapsida: Theria) de Colombia. *Biota Colombiana* 1(1): 43–75. <http://www.redalyc.org/pdf/491/49110103.pdf>
- Allen, J.A. 1914. Review of the genus *Microsciurus*. *Bulletin of the American Museum of Natural History* 33(11): 145–165. <http://hdl.handle.net/2246/1778>
- Anderson, S. 1960. The Baculum in Microtine rodents. University of Kansas Publications, Museum of Natural History 12(3): 181–216. <http://biodiversitylibrary.org/page/4392714>
- Anthony, H.E. and G.H.H. Tate. 1935. Notes on South American Mammalia. No. I. *Sciurillus*. *American Museum Novitates* 780: 1–13. <http://hdl.handle.net/2246/4570>
- Bezerra, A.M.R. Phallic morphology of *Kunsia tomentosus* (Rodentia: Sigmodontinae). *Mastozoología Neotropical* 12(2): 227–232. <http://www.scielo.org.ar/pdf/mznt/v12n2/v12n2a09.pdf>
- Buffon, G.L. 1789. *Histoire naturelle, générale et particulière: servant de suite à l'histoire des animaux quadrupèdes*. Paris, France: De l'Imprimerie Royale, Supplement 7: 364 pp.
- Burt, W.H. 1960. *Bacula of North American mammals*. Miscellaneous Publications Museum of Zoology, University of Michigan 113: 1–75. <http://hdl.handle.net/2027.42/56357>
- Cuervo Díaz, A., A.J. Hernández Camacho and A. Cadena G. 1986. Lista actualizada de los mamíferos de Colombia anotaciones sobre su distribución. *Caldasia* 15(71–75): 471–501. <http://www.revistas.unal.edu.co/index.php/cal/article/view/35095>
- de Vivo, M., and A.P. Carmignotto. 2015. Subfamily Sciurillinae Moore, 1959. Genus *Sciurillus* Thomas, 1914; pp. 3–9, in: J.L. Patton, U.F.J. Pardiñas, and G. D'Élia (eds.). *Mammals of South America: Rodents*. Volume 2. Chicago: University of Chicago Press.
- Díaz-N., J.F. 2012. New records of *Marmosops noctivagus* (Tschudi, 1845) (Didelphimorphia: Didelphidae) and first record of *Marmosops bishopi* (Pine, 1981) for Colombia. *Check List* 8(4): 805–809. <http://www.checklist.org.br/getpdf?NGD083-12>
- Didier R. 1955. Les pénien des ecreuils de l'Ameriqué du sud. *Mammalia* 19(3): 416–426. doi: [10.1515/mamm.1955.19.3.416](https://doi.org/10.1515/mamm.1955.19.3.416)
- Gascon, C., J.R. Malcolm, J.L. Patton, M.N.F. da Silva, J.P. Bogart, S.C. Loughheed, C.A. Peres, S. Neckel and P.T. Boag. 2000. Riverine barriers and the geographic distribution of Amazonian species. *Proceedings of the National Academy of Sciences of the United States of America* 97(25): 13672–13677. doi: [10.1073/pnas.230136397](https://doi.org/10.1073/pnas.230136397)
- Geoffroy Saint-Hilaire, É. 1803. *Catalogue des mammifères du Muséum National d'Histoire Naturelle*. Paris, France: Muséum National d'Histoire Naturelle. 272 pp. http://reader.digitale-sammlungen.de/de/fs1/object/display/bsb10482289_00181.html
- Gómez-Laverde, M., R.P. Anderson and L.F. García. 2004. Integrated systematic reevaluation of the Amazonian genus *Scolomys* (Rodentia: Sigmodontinae). *Mammalian Biology* 69(2): 119–140. doi: [10.1078/1616-5047-00126](https://doi.org/10.1078/1616-5047-00126)
- Hooper, E.T. and G.G. Musser. The glans penis in Neotropical Cricetines (Family Muridae) with comments on classification of Muroid rodents. *Miscellaneous Publications Museum of Zoology, University of Michigan* 123: 1–57. <http://hdl.handle.net/2027.42/56367>
- Husson, A.M. 1978. *The mammals of Suriname*. Netherlands: E. J. Brill, Leiden. 729 pp.
- Jansa, S.A., F.K. Barker and R.S. Voss. 2013. The early diversification history of didelphid marsupials: a window into South America's "splendid isolation". *Evolution* 68(3): 684–695. doi: [10.1111/evo.12290](https://doi.org/10.1111/evo.12290)
- Jessen, R., R.N. Gwinn and J.L. Koprowski. 2013. *Sciurillus pusillus* (Rodentia: Sciuridae). *Mammalian Species* 49(1): 75–79. doi: [10.1644/903.1](https://doi.org/10.1644/903.1)
- Mercer, J.M. and V.L. Roth. 2003. The effect of Cenozoic global change on squirrel phylogeny. *Science* 299(5612): 1568–1572. doi: [10.1126/science.1079705](https://doi.org/10.1126/science.1079705)
- Moore, J.C. 1959. Relationships among living squirrels of the Sciurinae. *Bulletin of the American Museum of Natural History* 118(4): 153–206. doi: <http://hdl.handle.net/2246/1265>
- Patterson, B., and C. Thaler. 1982. The mammalian baculum: hypotheses on the nature of bacular variability. *Journal of Mammalogy* 63(1):1–15. doi: [10.2307/1380665](https://doi.org/10.2307/1380665)
- Patton, J.L., M.N.F. da Silva and J.R. Malcolm. 2000. Mammals of the Rio Juruá and the evolutionary and ecological diversification of Amazonia. *Bulletin of the American Museum of Natural History* 244: 1–172. doi: [10.1206/0003-0090\(2000\)244<0001:MOTRJA>2.CO;2](https://doi.org/10.1206/0003-0090(2000)244<0001:MOTRJA>2.CO;2)
- Pessôa L.M., F.J. von Zuben and S.F. Reis. 1998. Morphological affinities of *Proechimys yonenangae* Rocha, 1995 (Rodentia: Echimyidae): evidence from bacular and cranial characters. *Bonner Zoologische Beiträge* 48(2):167–177. <http://biodiversitylibrary.org/page/44945204>
- Rocha-Barbosa, O., J.S.L. Bernardo, M.C.F. Loguercio, T.R.O. Freitas, J.R. Santos-Mallet and C.J. Bidau. 2012. Penial morphology in three species of Brazilian Tuco-tucos, *Ctenomys torquatus*, *C. minutus* and *C. flamarioni* (Rodentia: Ctenomyidae). *Brazilian Journal of Biology* 73(1): 201–209. doi: [10.1590/S1519-69842013000100022](https://doi.org/10.1590/S1519-69842013000100022)
- Rodríguez-Mahecha, J.V., J.I. Hernández-Camacho, T.R. Defler, M. Alberico, R.B. Mast, R.A. Mittermeier and A. Cadena. 1995. Mamíferos colombianos: sus nombres comunes e indígenas. *Occasional Papers in Conservation Biology, Conservation International* 3: 1–56.
- Roth, L.V. and J.M. Mercer. 2008. Differing rates of macroevolutionary diversification in arboreal squirrels. *Current Science* 95(7): 857–861. http://www.currentscience.ac.in/Downloads/article_id_095_07_0857_0861_o.pdf
- Rossi, R.V., R.S. Voss and D.P. Lunde. 2010. A revision of the didelphid marsupial genus *Marmosa*. Part 1, the species in Tate's 'mexicana' and 'mitis' sections and other closely related forms. *Bulletin of the American Museum of Natural History* 334: 1–83. doi: [10.1206/334.1](https://doi.org/10.1206/334.1)
- Solari, S., Y. Muñoz-Saba, J.V. Rodríguez-Mahecha, T.R. Defler, H.E. Ramírez-Chaves and F. Trujillo. 2013. Riqueza, endemismo y conservación de los mamíferos de Colombia. *Mastozoología Neotropical* 20(2): 301–365. doi: <http://www.scielo.org.ar/pdf/mznt/v20n2/v20n2a08.pdf>
- Thomas, O. 1914a. On a remarkable case of affinity between animals inhabiting Guiana, W. Africa, and the Malay Archipelago. *Proceedings of the Zoological Society of London* 84(2): 415–417. doi: [10.1111/j.1469-7998.1914.tb07046.x](https://doi.org/10.1111/j.1469-7998.1914.tb07046.x)
- Thomas, O. 1915. The penis-bone, or "baculum" as a guide to the classification of certain squirrels. *Annals and Magazine of Natural History, Series 8*, 15(88): 383–387. doi: [10.1080/00222931508693653](https://doi.org/10.1080/00222931508693653)
- Thorington, R.W. Jr., J.L. Koprowski, M.A. Steele and J. Whallon. 2012. *Squirrels of the world*. Baltimore, Maryland: Johns Hopkins University Press. 459 pp.
- Voss, R. S. and S. A. Jansa. 2009. Phylogenetic relationship and classification of didelphid marsupials, an extant radiation of New World Metatherian mammals. *Bulletin of the American Museum of Natural History* 322: 1–177. <http://hdl.handle.net/2246/5975>
- Wade, O. and P.T. Gilbert. 1940. The baculum of some Sciuridae and its significance in determining relationships. *Journal of Mammalogy* 21(1): 52–53. doi: [10.2307/1374657](https://doi.org/10.2307/1374657)
- Wassersug, R.J. 1976. A procedure for differential staining of cartilage and bone in whole formalin-fixed vertebrates. *Stain Technology* 51(2): 131–134. doi: [10.3109/10520297609116684](https://doi.org/10.3109/10520297609116684)

Wilson, D.E. and D.M. Reeder (eds.). 2005. Mammal species of the world: A taxonomic and geographic reference, 3th edition. Baltimore, Maryland: Johns Hopkins University Press. 2142 pp.

Authors' contribution statement: JFD and MCC conceived the study; HLA facilitated the loan of material between museums (ICN and IAvH) and provided all the logistics to work at ICN collection; MCC collected and recorded all the morphological data

including clearing and staining of baculum; JFD and MCC wrote the manuscript. The final version of the manuscript was approved by all authors.

Received: January 2015

Accepted: March 2015

Editorial responsibility: Terrence Demos